RILIS upgrade and LARIS scientific priorities

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Report to the Standing Group for the Upgrade of ISOLDE
13/11/2007
Reduction of planned RILIS operation time for 2007 down to 1500 hours has been recommended in the conclusions of the 2007 ATC/ABOC days.

No laser trouble happened during scheduled operation, all required service and repair work was performed between runs.
Upgrade of RILIS laser system

Stage 1: New pump lasers

Replacement of CVL by SSL

Advantages:
- Better beam quality
- Stability of operation
- Spectral coverage UV-NIR without gaps

Questions:
- New ionization schemes
- Reliability
- Service

Installation in shutdown 2007-2008

Wavelength tuning range:
Fundamental ($\omega$) 390 - 850 nm
2nd harmonic ($2\omega$) 210 - 425 nm
3rd harmonic ($3\omega$) 213 - 265 nm

Lasers: $f_{\text{rep}} = 11,000$ Hz, $t_{\text{pulse}} = 15$ ns
- 3 laser beams
- 2-3 Dye Lasers with Amplifiers
- Nonlinear Crystals BBO
- $P_{\omega} \leq 0.1 \text{ W}$
- $P_{2\omega} \leq 2 \text{ W}$
- $P_{3\omega} < 0.1 \text{ W}$
# Requirements to RILIS Solid State Lasers

<table>
<thead>
<tr>
<th></th>
<th><strong>Beam A - 532 nm</strong></th>
<th><strong>Beam B - 532 nm</strong></th>
<th><strong>Beam C - 355 nm</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam</strong></td>
<td>High quality beam for ionization</td>
<td>Medium quality beam for dye laser pumping</td>
<td>Medium quality beam for dye laser pumping</td>
</tr>
<tr>
<td><strong>Pulse repetition rate</strong></td>
<td>8-15 kHz</td>
<td>8-15 kHz</td>
<td>8-15 kHz</td>
</tr>
<tr>
<td><strong>Pulse duration</strong></td>
<td>10-30 ns</td>
<td>10-20 ns</td>
<td>10-20 ns</td>
</tr>
<tr>
<td><strong>Output pulse timing jitter</strong></td>
<td>&lt; 3 ns</td>
<td>&lt; 3 ns</td>
<td>&lt; 3 ns</td>
</tr>
<tr>
<td><strong>Average power</strong></td>
<td>40 W</td>
<td>30-40 W</td>
<td>15-20 W</td>
</tr>
<tr>
<td><strong>Power stability</strong></td>
<td>+/- 5% over 24 hours</td>
<td>+/- 5% over 24 hours</td>
<td>+/- 5% over 24 hours</td>
</tr>
<tr>
<td><strong>Beam divergence or M²</strong></td>
<td>&lt; 0.1 mrad after expanding to 20 mm diameter</td>
<td>M² = 5-20</td>
<td>M² = 15-20</td>
</tr>
<tr>
<td><strong>Beam pointing stability</strong></td>
<td>&lt; 0.02 mrad after expanding to 20 mm diameter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Laser market survey

Enquiries and contacts in 2003 – 2006:

1. Coherent Inc.  
   USA
2. Lambda Physik AG  
   Germany
3. Spectra-Physics LAS GmbH  
   Germany
4. Lightwave Electronics  
   USA
5. Quantronix Corporation  
   USA
6. Positive Light, Inc  
   USA
7. Spectron Laser GmbH  
   Germany
8. Groupe QUANTEL  
   France
9. LEE LASER, Inc  
   USA
10. THALES LASER S.A.  
    France
11. Photonics Industries International  
    USA
12. Powerlase Limited  
    UK
13. EdgeWave GmbH  
    Germany
14. General Atomics Photonics  
    USA

+ Contacts with other companies at Laser exhibitions at Munich (2003, 2005) and CLEO Conference
Lasers of EdgeWave GmbH, Germany

DIODE Pumped Nd:YAG, Nd:YLF and Nd:YVO₄ lasers

3 lasers:
2 x Green + 1 x UV

- Short cavity: naturally shorter pulses
- Specifications more or less satisfied in previously supplied lasers
- Separate laser system

- Small, relatively new company
- Long term availability of parts/service?

Nd:YLF, pulse length 10 ns at 10kHz, output average power 40W, $M^2 = 1.7$

Nd:YLF, pulse length 12 ns at 10kHz, output average power 20W, $M^2 = 4$,
SSL design proposal 1

<table>
<thead>
<tr>
<th>Beam A 532 nm</th>
<th>Beam B 532 nm</th>
<th>Beam C 355 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse duration</td>
<td>9 ns</td>
<td>9 ns</td>
</tr>
<tr>
<td>Jitter</td>
<td>&lt; 3 ns</td>
<td>&lt; 3 ns</td>
</tr>
<tr>
<td>Average power</td>
<td>40 W at 10 kHz</td>
<td>40 W at 10 kHz</td>
</tr>
<tr>
<td>Beam diameter</td>
<td>10 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>Beam divergence</td>
<td>&lt;0.2 mrad</td>
<td>0.2 mrad</td>
</tr>
<tr>
<td>Beam pointing stability</td>
<td>&lt;0.04 mrad</td>
<td>&lt;0.04 mrad</td>
</tr>
</tbody>
</table>

EdgeWave will build up a spare laser, incl. one laser head, one power supply and the software.

If failure happens, EdgeWave will send the spare laser immediately to CERN.
SSL design proposal 2

Suggested on 31.10.2007 following difficulty to fulfill the requirement of jitter < 3 ns

EdgeWave will build up two laser heads and power supplies.
- Both laser systems will be shipped to CERN.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+B</td>
<td>80W @ 532nm</td>
</tr>
<tr>
<td>C</td>
<td>20W @ 3nm</td>
</tr>
</tbody>
</table>

Warranty period = 2 years
+ 2 years of warranty extension included

Scheme of the Nd:YAG oscillator - amplifier
SSL implementation in RILIS room

- CVL oscillators
- CVL amplifiers
- CVL power supply
- Dye lasers
- SSL laser systems
- SSL power supply and chiller
- SSL laser systems
- Dye lasers
RILIS hardware

- CVL lasers
  - Built >15 years ago, to be replaced by Nd:YAG lasers
  - In operation during 2008

- Nd:YAG lasers
  - New, to be installed in 2008
  - Operation starting from 2008

- Dye lasers and dye amplifiers
  - Built >15 years ago
  - Upgrade planned for 2008-2009

- Non-linear optics elements
  - Consumable crystals
  - Could be included in new dye lasers (2009)

- Laser beam transport optics
  - Quartz prisms - losses > 40%
  - Minor improvements are possible

- Control tools
  - Currently only local control for most of parameters
  - Remote control is under development
Road map of RILIS upgrade

- Installation of solid state lasers for dye laser pumping. Keeping CVL lasers at RILIS as backup until reliable SSL performance is reached.


- Providing conditions for remote control of key RILIS parameters

- Including RILIS operation in the ISOLDE separator courses

- Switching RILIS running from “shift” to “on-call” operation mode

- Installation of Ti:Saphire lasers in addition to dye lasers

- Availability of RILIS for parallel running at GPS and HRS
Primary objectives:

- Investigate new ionization schemes (free from ISOLDE scheduling)
- Improve upon current schemes that rely on non-resonant ionization
  - search for auto-ionizing states
- Prepare for RILIS transition to Solid State Laser system
  - different wavelength range (532 nm and 355 nm pumped dye lasers)

Secondary objectives:

- Investigate RILIS selectivity improvements
  - HFS measurements (isomer selectivity)
  - Hot cavity optimization / material testing

Tertiary objectives:

- Questions related to fundamental atomic spectroscopy, e.g. accurate
determination of atomic ionization potentials.

CERN/KTH collaboration
LARIS laser photoinization spectrometer

Auto-ionizing state

IP

1

2

3

Nd:YAG 3

Nd:YAG 2

Nd:YAG 1

PDL

OPO 2

OPO 1

Gated integrator

Wavelength Meter

CEM

DC 3 kV

Pulsed 32 V

2ω generators

Auto-ionizing state
LARIS lasers

Spectra Physics Quanta-Ray PRO 230-10 + MOPO HF
Tuning range: 450 - 690 nm (signal), 730 - 1680 nm (idler),
2nd harmonics: 225 – 345 nm, 365 – 450 nm

Continuum PowerLite 7010 + OPO Mirage
Tuning range: 720 - 920 nm (fund.),
2nd harmonics: 360 - 460 nm

Lumonics Hyperdye dye laser pumped by Quantel Nd:YAG laser to be installed
Simple atomic beam setup

Current ABU system with oven:
- Measure relative efficiencies of ionization schemes
- Systematic study of auto-ionizing states
- New ionization schemes for currently unavailable elements
- Replace schemes that require CVL pumping at 511 nm

Later:
Upgrade to a more RILIS specific ABU (replica of ISOLDE target-ion source unit)
- Higher temperature
- Test cavity materials
- New ideas for better selectivity
To acquire higher resolution laser spectra for specific isotopes
- Measure isotope shifts for stable isotopes
- Measure HFS for different atomic transitions in various ionization schemes
- Feasibility study for *isomer separation*

Titanium atoms were:
- Ablated out of rod by Nd:YAG laser
- Transported by Ar gas
- Ionized by MOPO beam (294.2 nm)
- Mass-separated in TOF mass-spectrometer
- Detected with MCP
• Building 252-R-004
• 45 m²

For tests with ISOLDE target-ion source units an extension is envisaged:
• The neighboring room of 22 m² could be available after LHC completion
LARIS hardware

- Nd:YAG lasers
  - Built >5 years ago, in operation after service

- Optical parametric oscillators (OPO)
  - Built >5 years ago, in operation after service

- Dye laser
  - Built >10 years ago, ready for use

- Frequency doublers
  - One is new, another in operation after service

- Laser beam transport optics
  - New, assembling is going on

- Control tools
  - New commercial instruments

- Atomic beam unit
  - Assembled and tested with low temperature oven

- Time-of flight mass spectrometer
  - Built >5 years ago, in operation after service

- Ablation laser
  - New, purchased in 2007

- Data acquisition system
  - Under construction, based on commercial elements
# Budget plan

<table>
<thead>
<tr>
<th></th>
<th>2006 Spent</th>
<th>2007 Spent + Committed</th>
<th>2008 – 2009 To be spent</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RILIS Upgrade</td>
<td>0</td>
<td>705</td>
<td>845</td>
<td>1550</td>
</tr>
<tr>
<td>LARIS lab</td>
<td>224</td>
<td>170</td>
<td>306</td>
<td>700</td>
</tr>
<tr>
<td>Subsistence and travel</td>
<td>76</td>
<td>67</td>
<td>7</td>
<td>150</td>
</tr>
</tbody>
</table>

Grand Total = 2400 kCHF

Thanks to: Knut and Alice Wallenberg Foundation